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ABSTRACT

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Components in Hemispheric Lateralization

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Abstract

The fact that there is an imperfect correlation between the asymmetrical function of the two halves of the brain and handedness has been a source of puzzlement for many investigators. Many theories have been proposed to explain handedness and why handedness does not correlate perfectly with other measures of lateralization. To assess the relationships among the various aspects of laterality, the present study attempted to isolate factors that underlie lateralization by means of a factor analytic technique. A principal components analysis of the scores of 261 college student subjects on 15 measures of lateralization isolated six factors which accounted for 59.5% of the variance in the scores. The results tend to confirm that left handers are not as strongly lateralized as right handers, and that females are not as strongly lateralized as males in some measures. Most important, however, is the indication that hemispheric lateralization is clearly a multidimensional phenomenon rather than simply a matter of general right- or left-sidedness.

Components in Hemispheric Lateralization

In the 1960s, investigators like Gazzaniga, Bogen, and Sperry (1962) working with split-brain patients, and Geschwind and Kaplan (1962), studying the role of the corpus callosum, validated Broca's century-old claim that the two halves of a human brain are functionally asymmetric. During the past 25 years, hemispheric asymmetry has been under intense examination (for reviews, see Beaumont, 1982; Beaton, 1985).

One subject of investigation is handedness. Structurally, numerous anatomical difference have been documented for the hemisphere that subserves speech (e.g., Galaburda, 1984; Geschwind & Levitsky 1968; Witelson, 1980). Witelson's (1980) review of the literature showed a consistent correlation between the direction of anatomical asymmetry and hand preference. However, asymmetry in neural anatomy does not necessarily cause handedness. Does larger necessarily indicate better? Also, does larger mean that a structure subserves more complex functions? Many researchers have wondered why more than 95% of right handers have a left hemisphere speech site, or why 70% of left-handers have speech in the left hemisphere. Only 15% of left handers have the right hemisphere subserving their language function, and the remaining 15% have both right and left

hemisphere representation (Rasmussen & Milner, 1977). Many theories of handedness have been proposed (Annett, 1985; Bakan, 1971; Levy-Nagylaki, 1972; Satz, 1972; Silverberg, Obler & Gorden, 1979.) Levy and Reid (1976) postulated that an inverted writing posture indicates that the speech hemisphere is ipsilateral to the preferred hand. Individuals with non-inverted writing are hypothesized to have their speech site in the hemisphere contralateral to their writing hand. Whether or not Levy and Reid are correct, it is clear from the known failure to find a perfect correlation between handedness and speech side that lateralization is not a simple all-or-none, left-or-right phenomenon.

In studying the apraxias, a disorder of learned movement, Geschwind (1975) proposed the concept of a multiple motor system. He suggested that pyramidal systems arising from the precentral gyrus control limbs of the opposite side and finger movements, whereas nonpyramidal systems arising from multiple sites in the cortex (one particular site of these is Wernicke's area) control axial muscles: eye, neck, sides of the body, and turning. Geschwind suggested that these systems are independent of one another.

Luria (1970), in a somewhat similar view, suggested a concept of latent handedness. Latent left-handers are

those right-handed individuals who show signs of left-handedness. Luria found that latent left handers recover from traumatic aphasia (brain damage resulting in loss of ability to articulate ideas) much like left-handers, and differ from pure right handers. Luria proposed special tests for latent left-handedness as one of the methods for examining the higher cortical functions. These tests include: folding hands, interlacing fingers, crossing arms, and eye dominance. In testing the validity of Luria's supposition, Sakano (1982) found, among other things, that the proportion of latent right- and left-handers in the normal population is about 1:1, that the arm crossing test is the most effective index of latent handedness, and that the manner of folding arms is related to measured intelligence, especially in females. Simple latent handedness measures, if they are shown to be useful in predicting recovery from aphasia, proneness to dyslexia, etc., could be used readily in clinical settings with little cost. The present study is an attempt to test whether lateralization is a unidimensional phenomenon or, as the work of Luria and Sakano, and Geschwind's theory, suggest, a multidimensional phenomenon. In our principal components analysis, we have added a number of variables to the measures used by Luria and Sakano.

Method

Subjects

Two hundred sixty one undergraduate students (99 females who write with the right hand and 52 who write with the left hand, and 59 males who write with the right hand and 51 who write with the left hand) participated in the study as part of a requirement for an introductory psychology course at San Diego State University.

Procedure

Subjects were tested one at a time. The experimenters noted the following first two items as subjects signed the consent forms, and proceeded to ask about the rest of these items and noted subjects' responses:

1) Which hand is used in writing.
2) Writing posture.
3) Please cross your legs above your knee. (Noted right or left on top.)
4) Which side of your body do you sleep on most often? (Noted right or left.)
5) When you sleep on your stomach, which ear is on the pillow most often? (Noted right or left.)
6) Please wink at me. (Noted right or left eye closed.)

7) Please fold your hands, interlacing your fingers. (Noted right or left thumb on top.)

8) Please cross your legs at the ankles. (Noted left or right on top.)

9) Please fold your arms. (Noted left or right on top.)

10) Please point to the spot on the wall (10 feet away from where the subjects were sitting) with both of your eyes open. Now, I am going to cover your eyes one at a time; please tell me if your finger seems to jump from the spot at which you are pointing. If your finger jumped both times, please tell me which time it jumps more. (Which eye was covered when the image jumped was noted; if it jumped both times, a second test was administered and the side that jumped more was noted.)

11) Please stand up and line your toes against the line on the floor in front of you. Now, please walk across the room. (Which leg goes out first noted.)

12) Please turn around. (Turning right or left noted.)

13) Please allow yourself to begin falling forward until you extend a leg to break the fall. (Noted which leg has been extended.)

14) Please sit down. On this paper you see 6 X's. Please draw a circle around each of the first set of 3 with your right hand. (A clockwise circle was

classified as a right torque, and a counterclockwise circle, no right torque.)

15) Now, circle the other 3 with your left hand, please. (A clockwise circle was a left torque, and a counterclockwise circle, no left torque.)

Results

The 15 measures of lateralization, together with gender, were submitted to SPSS-X factor analysis. Six factors which accounted for 59.5% of the variance in the scores were isolated. The Eigenvalues for the six factors are 3.03, 1.54, 1.47, 1.29, 1.11 and 1.09. Factor I relates strongly with which hand is used for writing (.77 loading), hand posture used when writing (.75 loading), which eye is dominant (.57 loading), and the way a person draws a circle on paper with the right hand (.57). Factor II draws heavily on the way individuals cross their legs and cross their ankles, as well as on which leg is extended to prevent a fall (.83, .77, and .59 loading respectively). Factor III consists of which ear a person puts on the pillow when sleeping on the stomach and which side of the body a person sleeps on most often (.75 and .72 loading respectively). Factor IV is strongly related to how a person turns around (.73 negative loading), and which eye a person uses to wink (.54 loading). Factor V is composed of

whether a person is male or female and the manner in which he/she folds his/her arms (.83 and .65 loading respectively). Finally, factor VI is strongly related to how individuals fold their fingers, as well as to the way they draw a circle on paper using their left hand (.82 and -.54 loading respectively). Table 1 shows the rotated factor matrix; loading in excess of .45, or 20%, are followed by two asterisks.

A crosstabulation of writing hand with every other variable, controlling for sex, was performed. Table 2 shows the chi-square for each tabulation. The actual percentages of the cases observed in each category are presented in Figure 1 a-n.

Insert tables 1 and 2 and figure 1 a-n about here

Discussion

The present data indicate that latent handedness is a multidimensional phenomenon. For example, leg preference, which loaded on Factor II, is clearly independent of hand preference, which loaded on Factor I. Presuming that placing the right ear on the pillow is an indication of preferring to leave the left ear open for subconscious listening when one is sleeping, the lateralities of ear preference and eye preference

(winking) are clearly independent of one another (loading on Factor III and IV respectively). Furthermore, winking, which involves muscles, is independent of eye dominance, which involves perception. They load separately on Factor I and Factor IV. Even the lateralities of fingers and arms are independent of one another. Arm crossing manner is loaded on Factor V and finger crossing on Factor VI.

The present data show that only 9% of female and 3% of male right-handers exhibit the inverted writing posture, whereas 42% of female and 71% of male left-handers do so. These percentages are consistent with the percentages of people who have speech subserved by the left hemisphere (at least 95% of right handers and 70% of left handers). Our data are therefore consistent with the Levy and Reid (1976) hypothesis that people who write with an inverted hand posture have ipsilateral speech localization.

The interrelationships comprising Factor I confirm that there is not a perfect correlation between hand preference and eye domination (e.g. Downey, 1927; Merrell, 1957).

In drawing, there are differences between drawing with the right and left hands, and between right- and left-handers (Figure 1 i & j). This kind of

inconsistency may help to explain why some individuals write with the left hand and yet draw with the right hand (Geschwind 1985). Geschwind maintained that drawing is subserved by the nonpyramidal motor system, and writing is subserved by the pyramidal motor system. It is interesting to note the resemblance in figure 1 i and m for right handers but not for left handers. The percentage of right handers who have inverted writing posture is similar to the percentage who have "right torque" and these measures are both associated with Factor I. Thus inversion and torque may both be determined in similar fashions, whether or not inverted handwriting is related to having speech controlled by the hemisphere ipsilateral to the writing hand.

Our data also provide support for Geschwind's (1975) hypothesis that the nonpyramidal motor system controls facial muscles and the body trunk, and that the pyramidal motor system controls the limbs. Table I shows that side preference in winking the eye was not related to writing hand (Factors I and IV); yet there is a relationship between winking and turning around (Factor IV). To turn around, one must pick up the right leg in order to turn left; thus the data are consistent with which leg is extended to walk and to prevent oneself from falling. However, the phenomenon also

could be explained from a different point of view. Turning involves the trunk of the body, and the part of the motor system, nonpyramidal, that subserves the body trunk is different from the part that subserves the limbs, the pyramidal system. This could account for separation of Factors II and IV and provide further support for Geschwind's (1975) hypothesis.

As indicated above, laterality of hand preference is independent of arm crossing preference. More males put their left arm as well as left thumb on top; females tend to split evenly on both. With a small sample of 50, Annett (quoted in Sakano, 1982) found that the way in which the arms are crossed does not correlate with handedness. Sakano (1982), on the other hand, found that there is a strong correlation between the two categories. Sakano did not report the actual number of males and females in each case. The present data show that 76% of right-handed, as well as 65% of left-handed, males put their left arms on top; females show a more even split (Figure 1 a & b). Could there be a cultural difference between Sakano's Japanese and our US subjects? In any case, our data are consistent with the view that females are less lateralized. It is of some interest to note that sex and arm crossing load on the same factor, confirming Sakano's (1982) finding that

these variables are somehow related. Sakano was studying consistency of mode of crossing over time, and we were not; thus our data demonstrate that, even in a cross-sectional view, there is some peculiarity in the relationship between sex and mode of arm crossing.

Luria's (1970) three criteria for latent handedness are situated on three different dimensions of lateralization (see Table 1): eye dominance loaded on Factor I, the manner of folding arms on Factor V, and the manner of folding fingers on Factor VI. Further work along the lines of the current study might result in better and purer measures of latent handedness and aspects of lateralization.

In general, the present data further confirm that left handers are not as strongly lateralized as right handers. More important, lateralization is not a unidimensional phenomenon.

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Table 1
Component Structure, a Rotated Factor Matrix

VARIABLES	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
Leg Crossing	- .02	.83**	.12	- .14	- .00	- .04
Ankle Crossing	.14	.77**	.21	- .09	- .02	- .07
Walk	.42	.36	- .36	.07	- .03	- .28
Falling Leg Ext.	.33	.59 **	- .20	.29	.10	.01
Turning Around	.02	.20	- .06	- .73**	.01	- .01
Wink	- .05	.30	.28	.54**	.11	- .08
Sleep Side	.21	.08	.72**	.14	- .09	.03
Ear on Pillow	.14	.11	.75**	.05	.01	- .08
Hand Crossing	- .06	.12	.11	- .17	.04	.82**
Arm Crossing	- .10	.05	- .03	- .13	.83**	- .09
Circling R-hand	.57**	- .08	.22	.04	.25	.04
Circling L-hand	- .03	.13	.26	- .29	.07	- .54**
Eye Dominance	.57**	.06	.05	- .34	.06	- .12
Inversion	.75**	.11	.04	.06	- .04	.13
Writing Hand	.77**	.22	.22	- .00	- .00	- .15
Sex	.30	- .02	- .05	.28	.65**	.10

** Variables that Predict at Least 20% of a component's Variance.

Table 2

Chi-Square Values From Crosstabulation of Writing Hand by Every Variable Controlling for Sex.

Write by Variable	Female	Male
Leg Crossing	2.08	6.58**
Sleep Side	11.28***	7.08**
Ear On Pillow	6.93**	8.59**
Wink	2.68	1.57
Hand Crossing	1.990	.93
Ankle Crossing	14.43***	11.30***
Arm Crossing	0.411	.77
Walk	6.66**	11.27***
Turn Around	.322	.83
Falling	6.84**	13.79***
Circling R-hand	9.33**	24.42***
Circling L-hand	9.29**	0.00
Eye Dominance	15.80**	18.76***
Inversion	22.37***	54.63***

* p<.05 **p<.01 ***p<.001

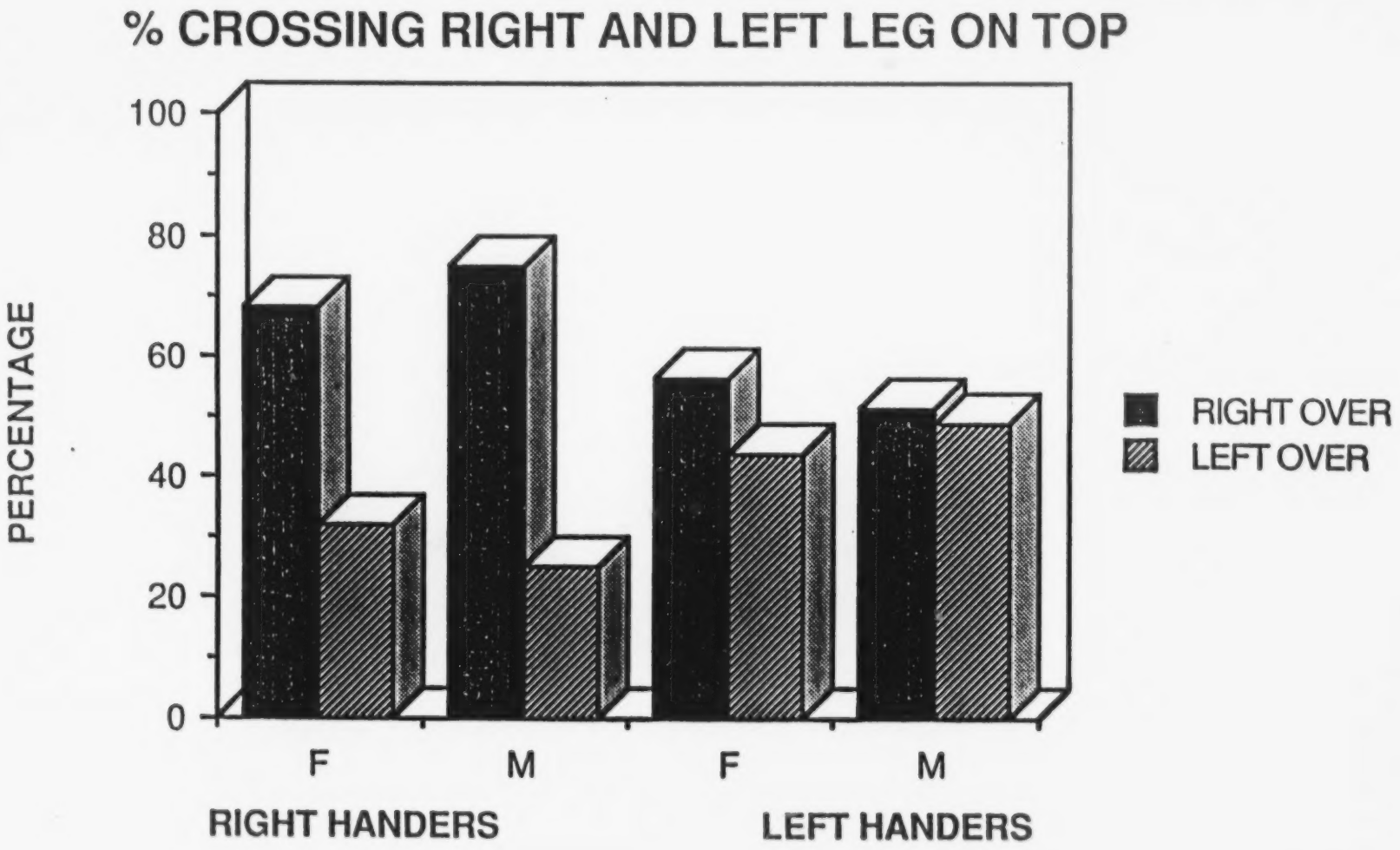

Fig. 1-a Percentage of right- and left-handed writers in the manner of crossing legs.

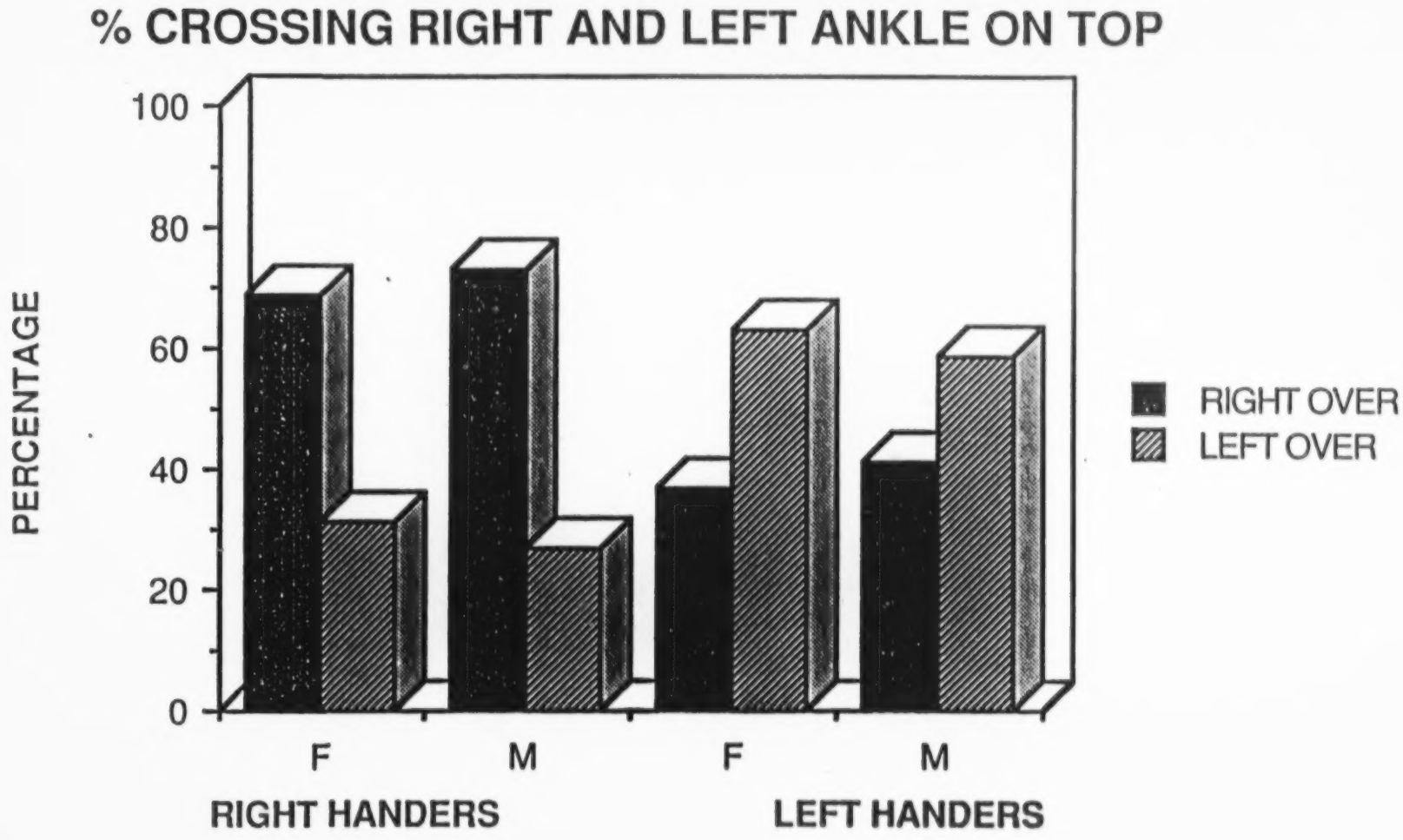

Fig. 1-b Percentage of right- and left-handed writers in the manner of crossing ankles.

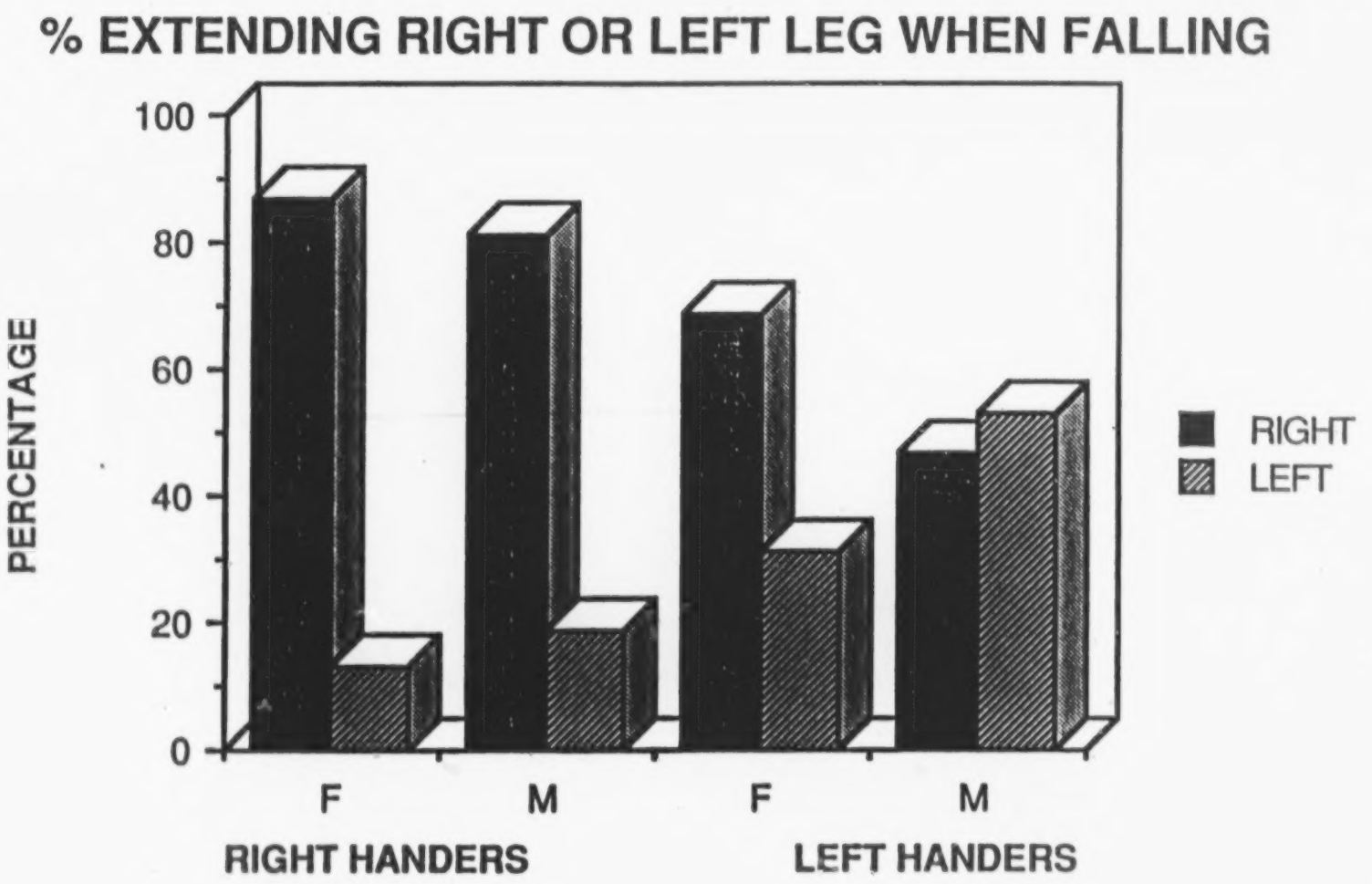

Fig. 1-c Percentage of right- and left-handed writers in the manner or extending a leg to prevent a fall.

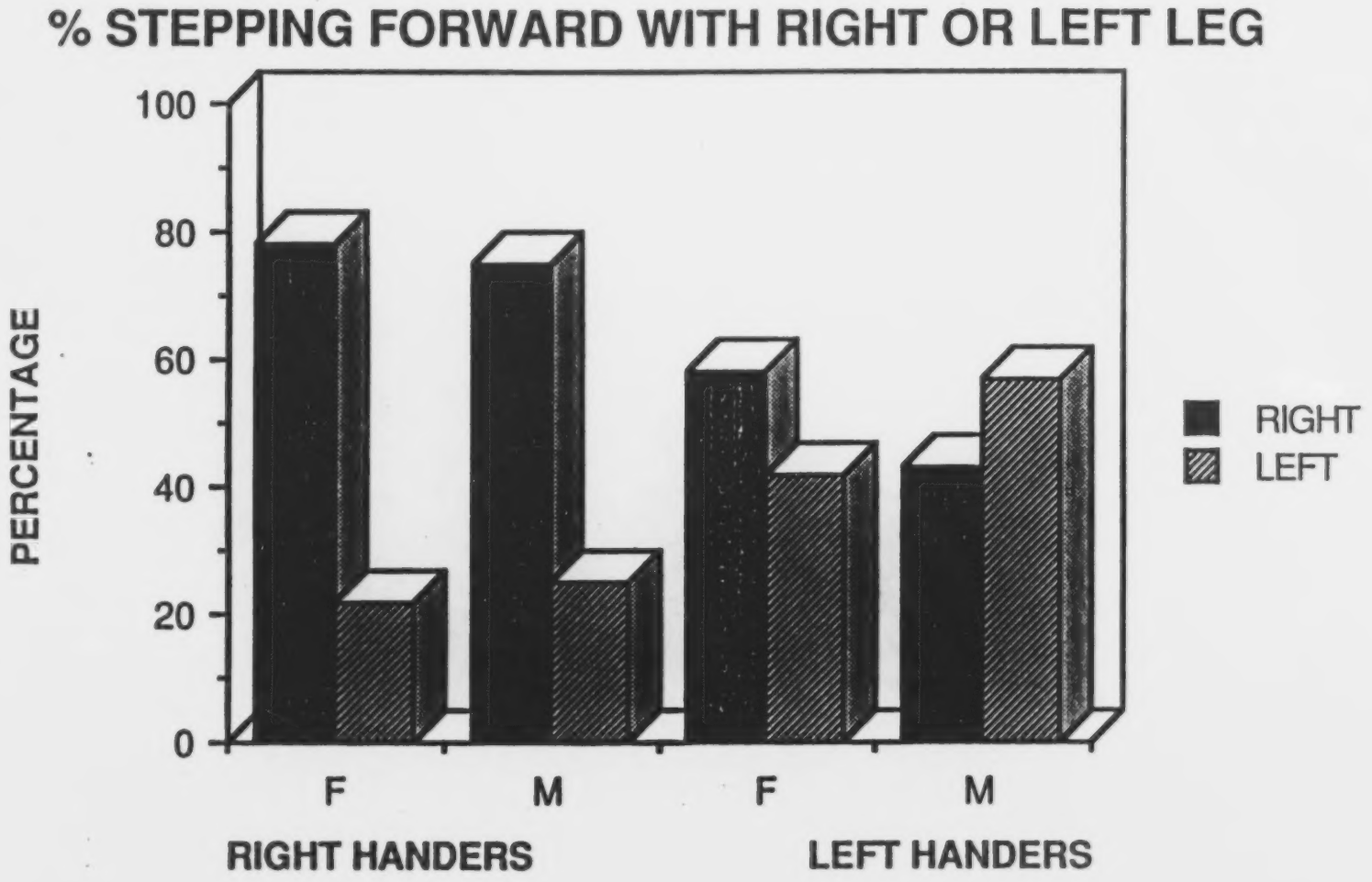

Fig. 1-d Percentage of right- and left-handed writers in the manner of starting to walk.

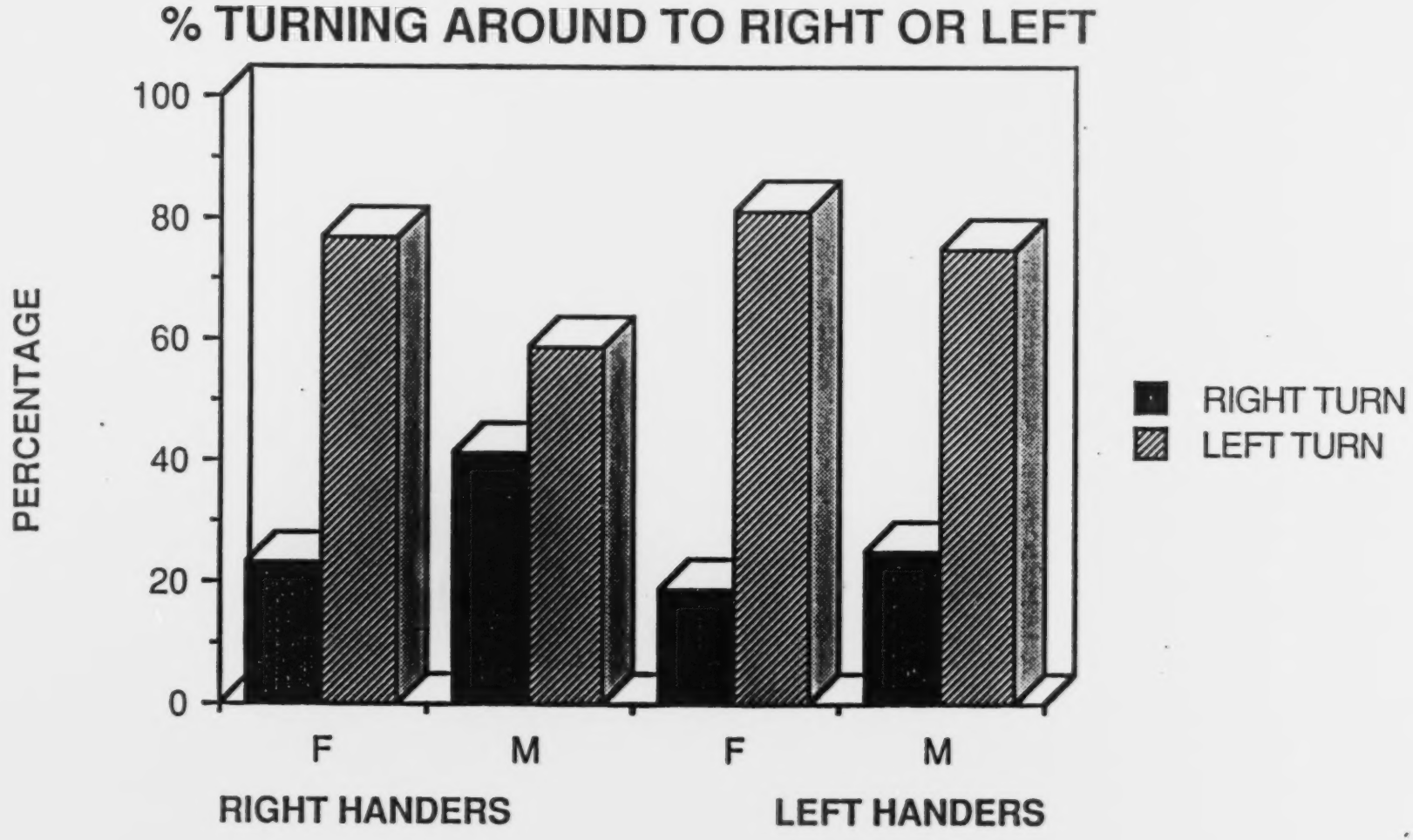

Fig. 1-e Percentage of right- and left-handed writers in the manner of turning around.

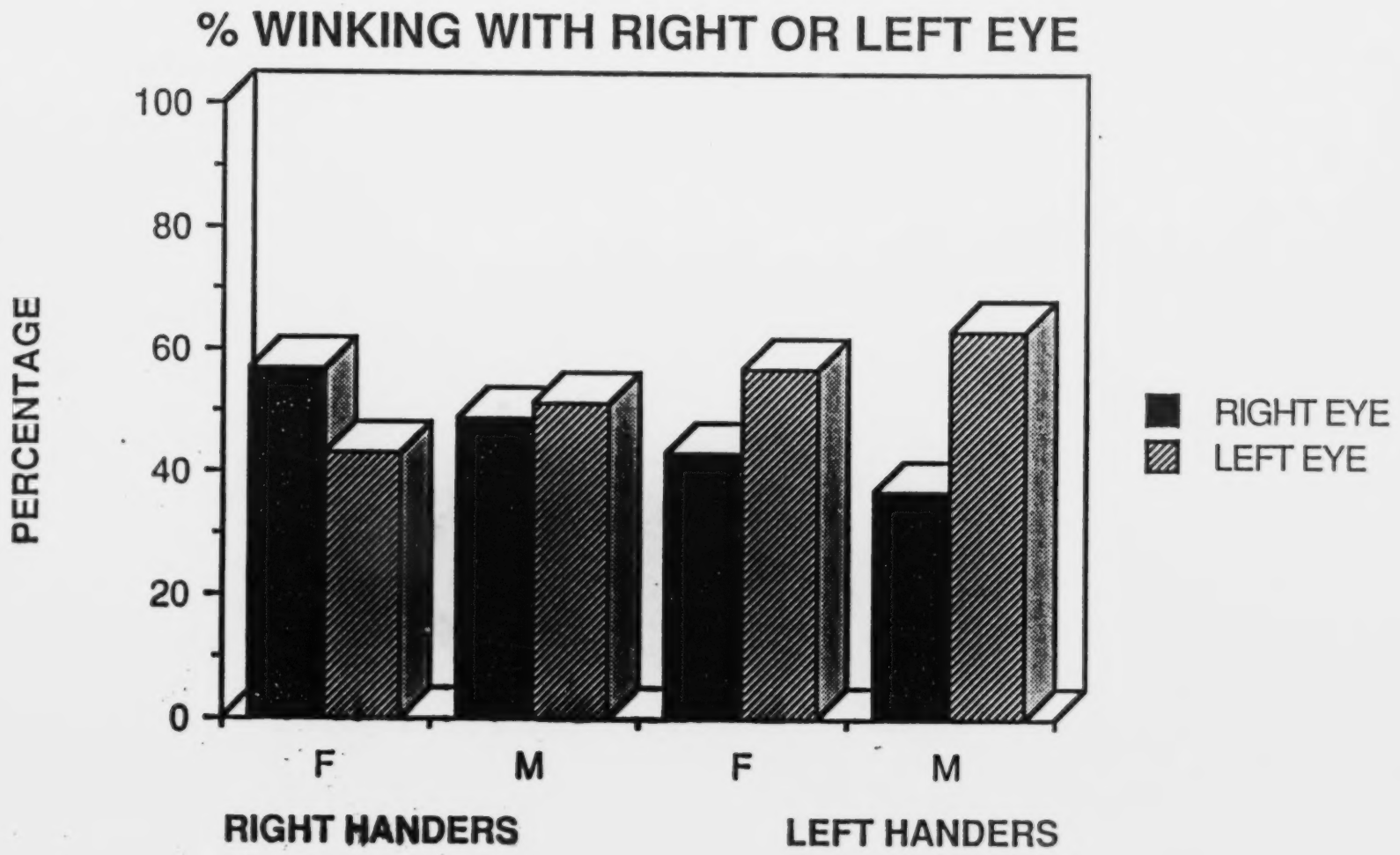

Fig. 1-f Percentage of right- and left-handed writers in the manner of winking.

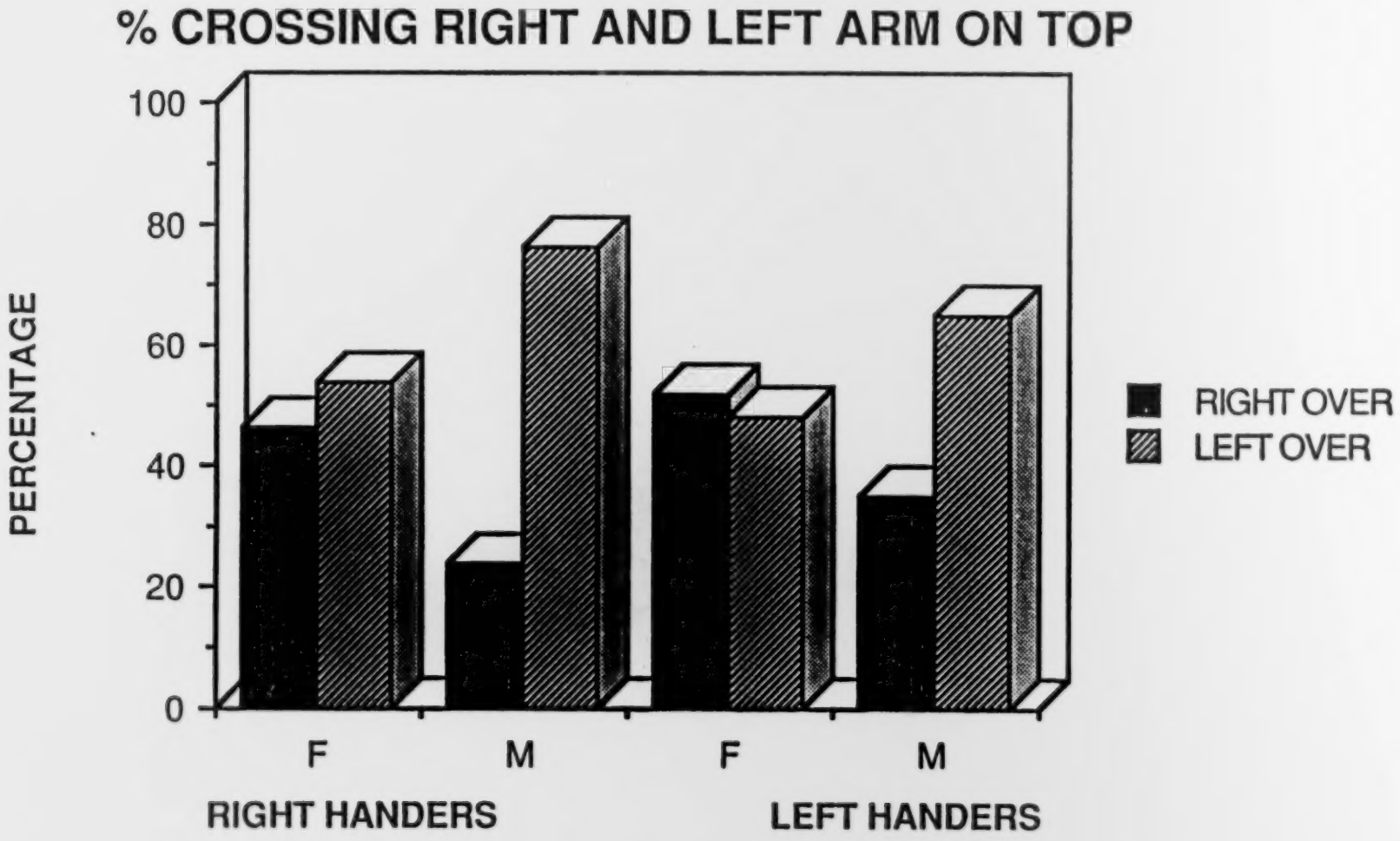

Fig. 1-g Percentage of right- and left-handed writers in the manner of arm crossing.

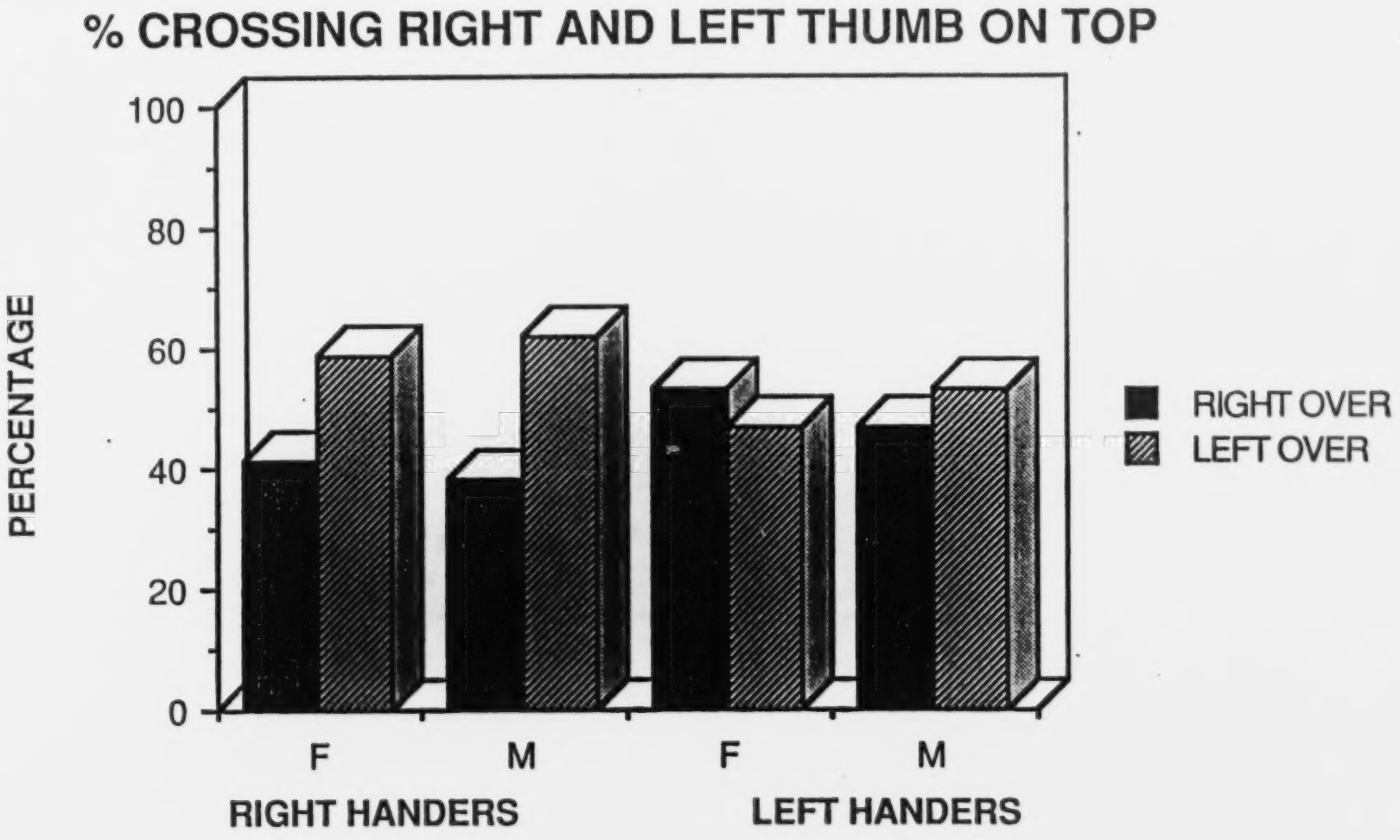

Fig. 1-h Percentage of right- and left-handed writers in the manner of finger crossing.

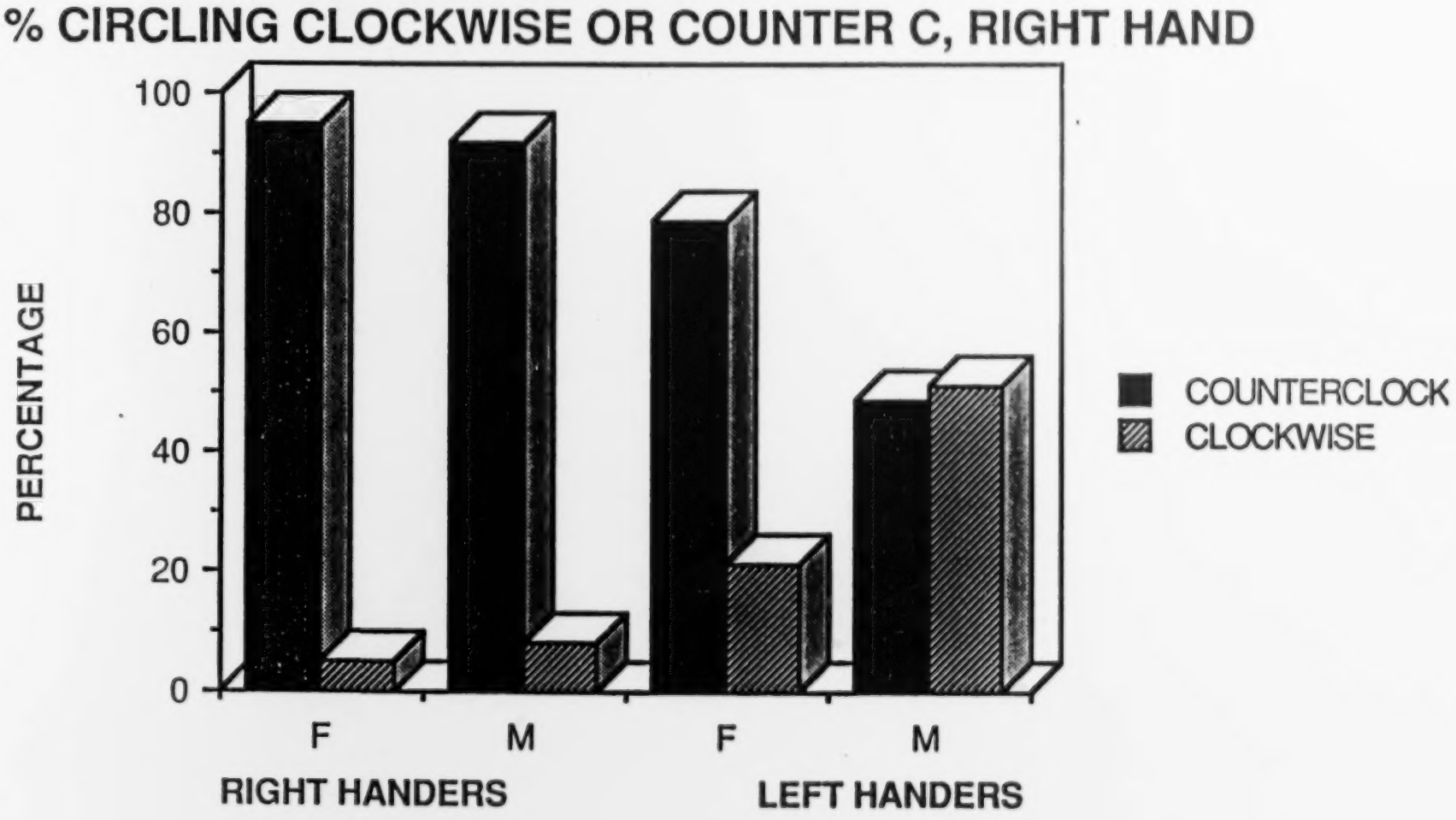

Fig. 1-1 Percentage of right- and left-handed writers in the manner of drawing a circle around a target on paper with the right hand.

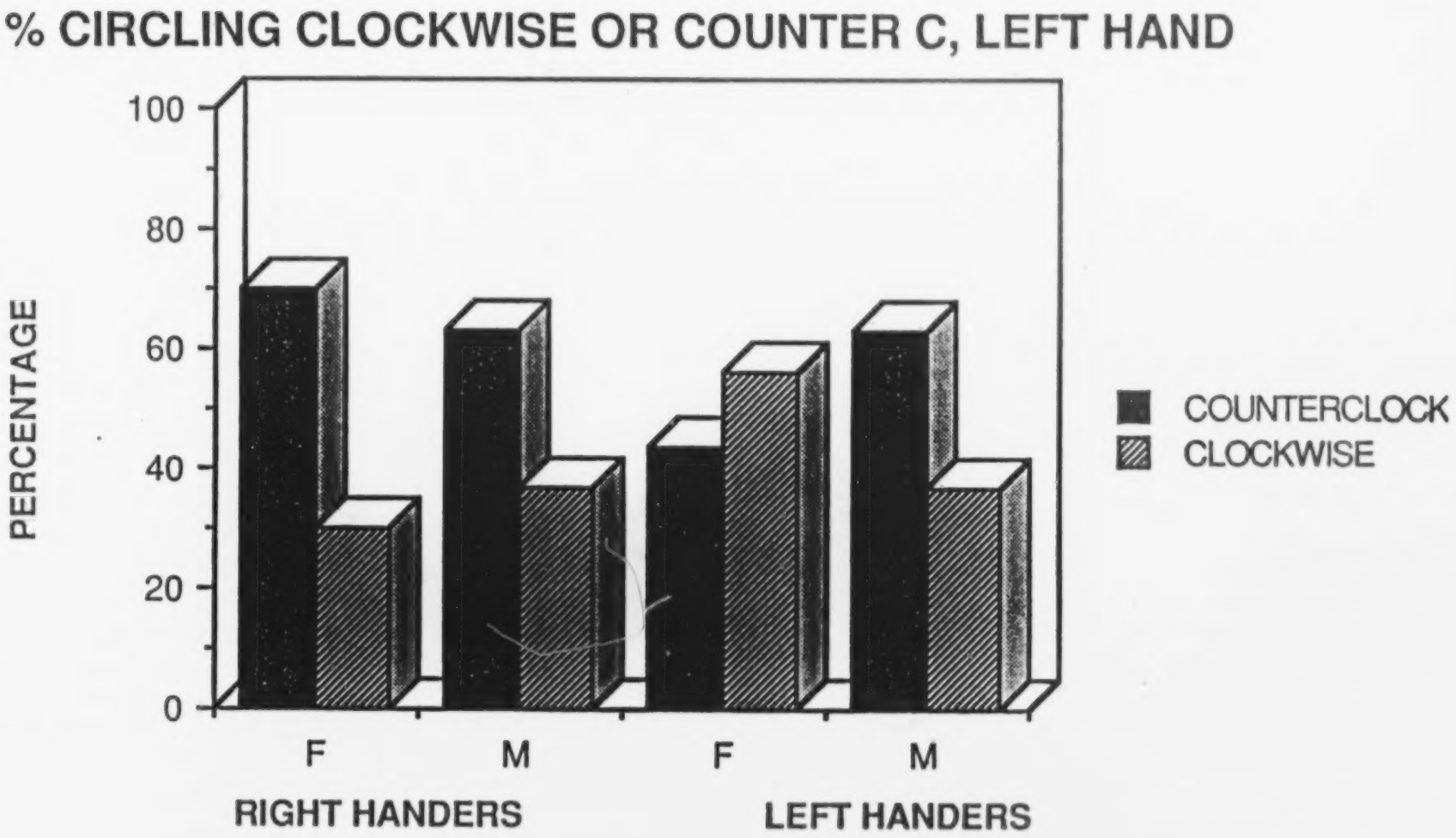

Fig. 1-j Percentage of right- and left-handed writers in the manner of drawing a circle around a target on paper with the left hand.

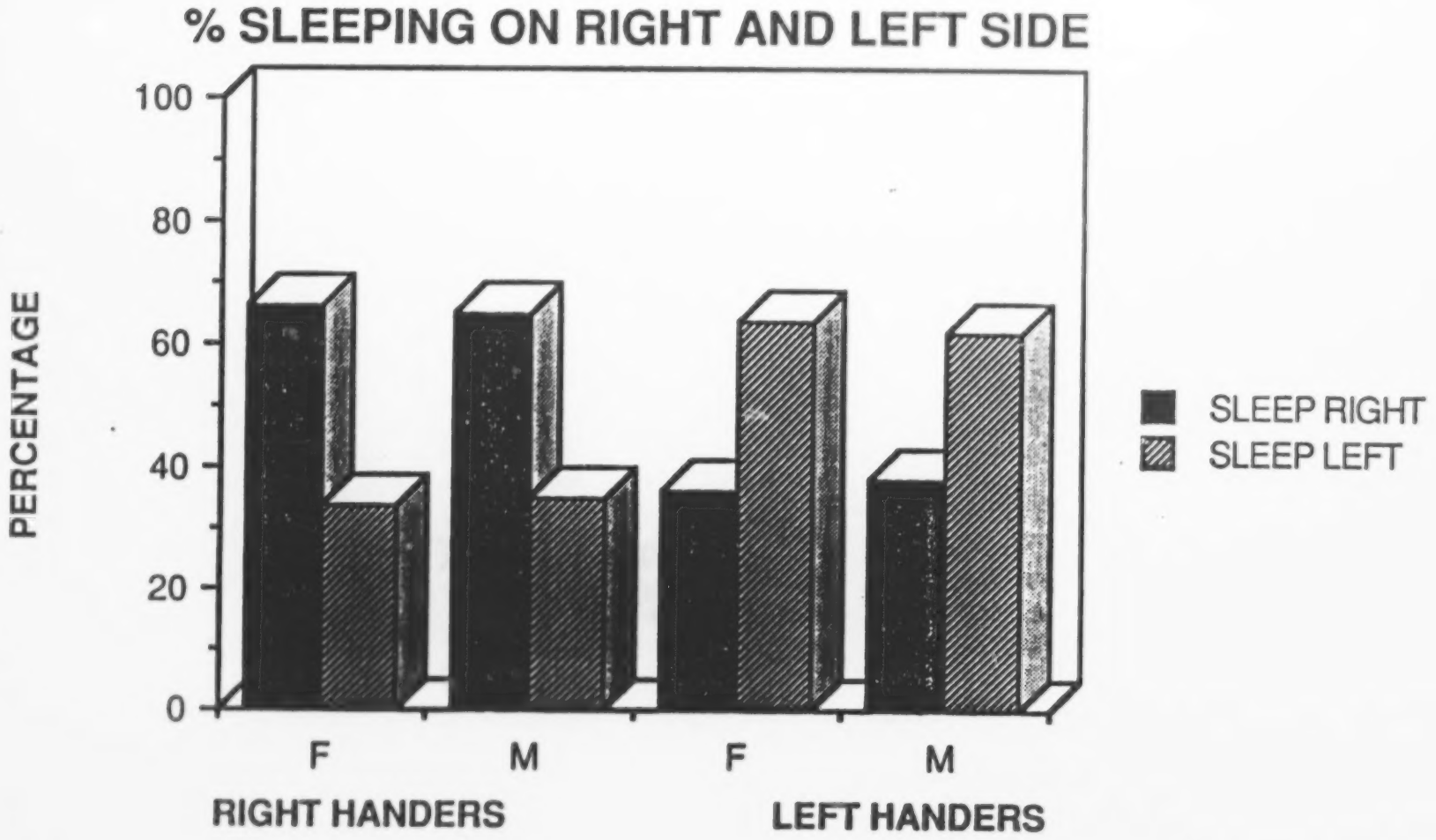

Fig. 1-k Percentage of right- and left-handed writers on the side of the body a person sleeps on most often.

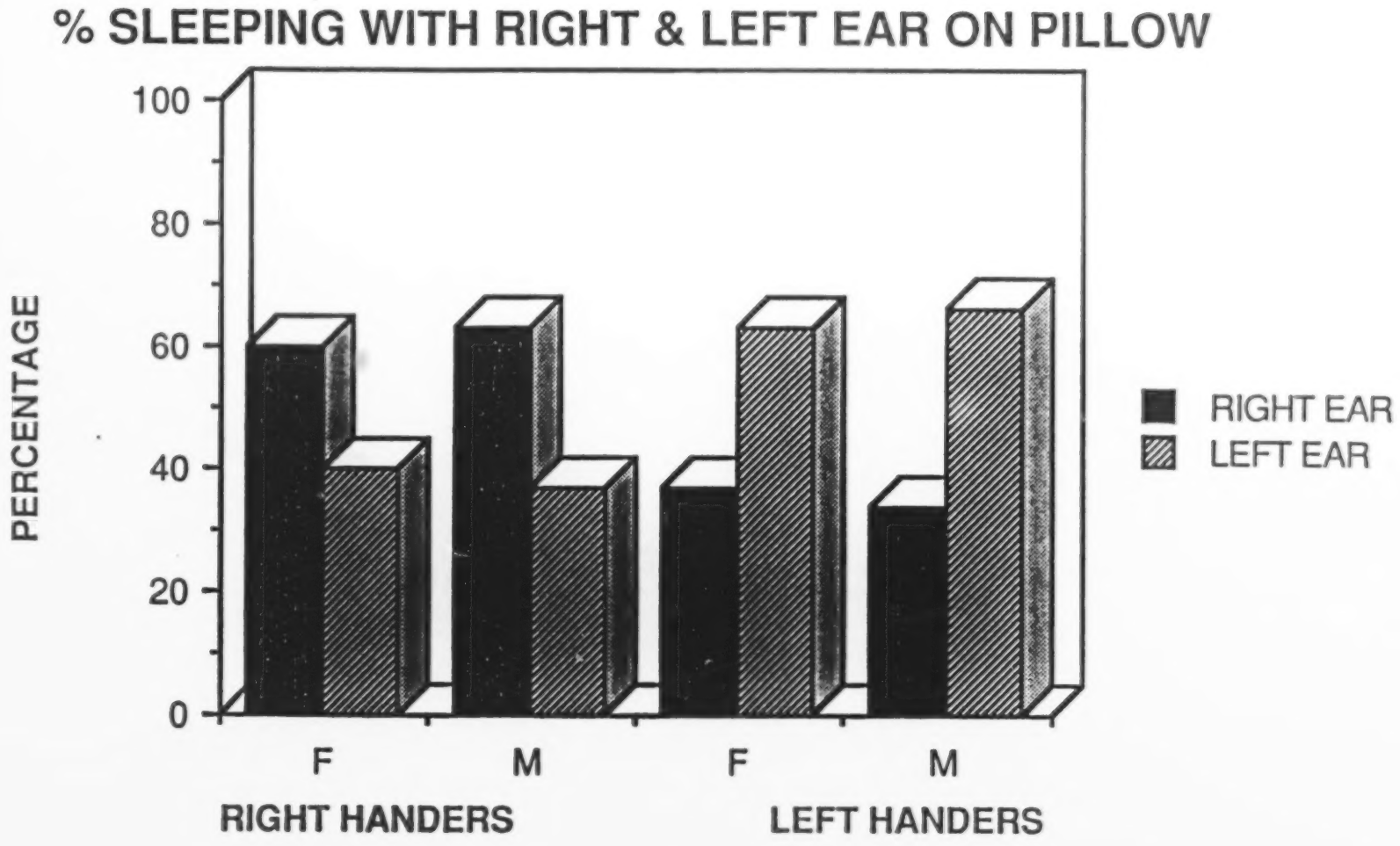

Fig. 1-ℓ Percentage of right- and left-handed writers in right or left ear placed on pillow when a person is sleeping on his/her stomach.

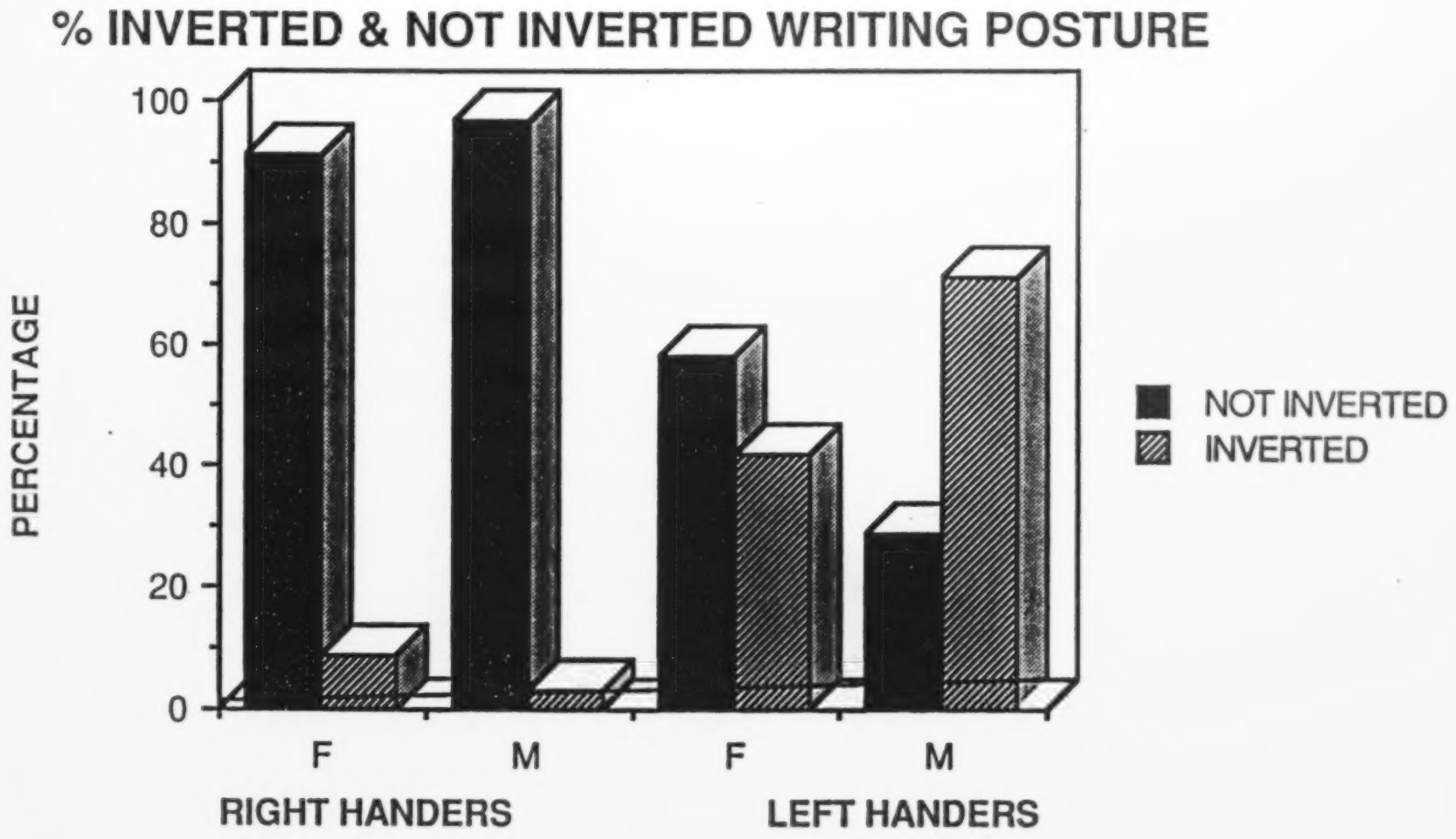

Fig. 1-m Percentage of right- and left-handed writers in writing hand posture.

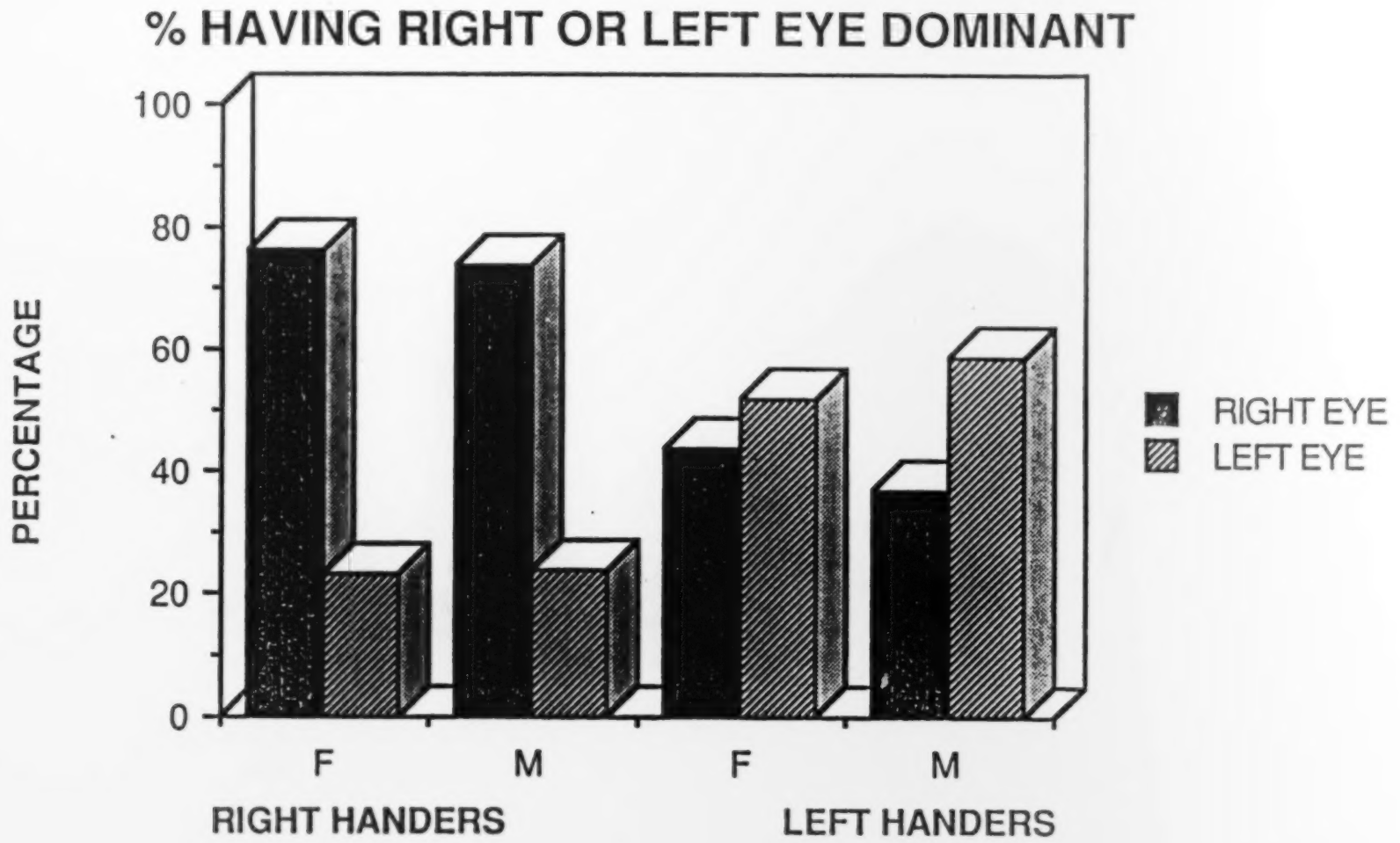

Fig. 1-n Percentage of right- and left-handed writers in eye dominance.